UNIVERSITY AND EDUCATIONAL NEWS

THE sum of $40,000 has been given by Mr. Andrew Carnegie to Allegheny College for a chemical laboratory to replace the one recently destroyed by fire.

MR. PATTEN, who has already given $500,000 to the medical school of Northwestern University, has now added $27,000 for scholarships.

PROFESSOR C. H. PEABODY, head of the department of naval architecture at the Massachusetts Institute of Technology, has been notified by the Aero Club of America of the establishment of an award in the form of a medal for the students at the institute. The medal is to be termed the "Aeronautical Engineers' Medal" and is for award annually for merit to a student in the graduate course in aeronautical engineering.

AT the University of Chicago Dr. Frank Christian Becht has been appointed assistant professor in the department of physiology, his particular field of work being pharmacology. Professor Becht, who is a graduate of the University of Chicago, was for two years assistant professor of physiology in the University of Illinois and later assistant professor of pharmacology in the Northwestern University Medical School.

IN the medical department of the University of Oregon Dr. J. M. Connolly has resigned as professor of physiological chemistry and Dr. H. D. Haskins, of Western Reserve University, Cleveland, has been elected his successor. Dr. B. L. Arms has resigned as professor of bacteriology to accept a position in the University of Texas and Dr. W. H. Norton, of Johns Hopkins Medical School, has been appointed to the vacant position.

Two professors from Louvain University—MM. Charles Jean de Valée Poussin and Léon Dupriez—have been invited by Harvard University to deliver lectures in the second semester. The former will lecture on mathematics, the latter will give the Godkin lectures on "Proportional Representation in Belgium" and two courses.

DISCUSSION AND CORRESPONDENCE

THE FUNDAMENTAL EQUATION OF MECHANICS

IN his recent review of Maurer's "Technical Mechanics,"[1] Professor L. M. Hoskins has discussed at some length the question whether $F = ma$ or $F/F' = a/a'$ is the better form in which to introduce the "fundamental equation of mechanics." As Professor Hoskins' defense of the equation $F = ma$ is the clearest I have seen, and as I am still one of those who prefer the equation $F/F' = a/a'$, I should like to state here the advantages which this latter equation seems to me to possess.

In the first place, the qualitative notion of *force*, and the use of the *spring balance* as an instrument for the quantitative measurement of forces, may safely be assumed to be familiar to any one beginning the study of mechanics.[2]

The first serious problem, then, which confronts the teacher of dynamics is the problem of making the student understand the effect which a force produces when it acts on a material particle. This effect is, of course, the acceleration of the particle in the direction of the force, the exact quantitative relation being most simply stated as follows:

If a given particle is acted on at two different times by two forces F and F', and if a

[1] SCIENCE, December 4, 1914.

[2] The question of the unit of force, which occupies so large a place at the very beginning of the subject in the ordinary treatment, need not be dwelt upon at this stage. To the beginner, a unit force is quite properly any force which brings the pointer of a standard spring balance to the point marked "1" on the scale, whether the instrument reads pounds, or dynes, or grams; just as a degree of temperature is, to the beginner, simply the distance between two divisions of the scale of a standard thermometer, whether that scale reads Fahrenheit, Réaumur or Centigrade. The conversion factors connecting the various degrees of temperature should indeed be stated; but the question of ultimate standards, being chiefly a question for the technician, need not be raised at this point. For further details, see the writer's "Recommendations Concerning the Units of Force," in the *Bulletin of the Society for the Promotion of Engineering Education*, June, 1913, the most important of which have already been adopted by the U. S. Bureau of Standards.

and a' are the corresponding accelerations, then $F/F' = a/a'$; that is, the accelerations are proportional to the forces.

When once this simple principle is thoroughly grasped, the student finds himself immediately in a positon to attack any of the elementary problems in the dynamics of a particle (in one dimension). For, by this principle, the effect of any force on a given particle can at once be computed if the effect of any one force on that particle is known. In other words *the dynamical properties of any given particle of matter are completely determined by a single physical experiment on that particle,* and the result of such an experiment must be known or assumed with regard to every particle which enters into the discussion of a dynamical problem.[3] It is the chief advantage of the equation $F/F' = a/a'$ that by its use the student is led, by the shortest possible route, into direct and vital contact with this central fact of dynamics—namely, that different bodies require different amounts of force to give them any specified acceleration. The whole further development of the science is essentially a matter of working out details, and introducing convenient terminology for such derived quantities as mass, momentum, kinetic energy, work, power, etc.

What then is the objection to the use of this equation?

Professor Hoskins expresses his objection as follows:

> An equation which results from comparing the effects of different forces *upon the same body* can not, of course, be regarded as a complete expression of the fundamental law of motion; it is equally important to compare the effects of forces *acting upon any different bodies.* This of necessity brings in the body constant which most physicists call mass.

In reply to this objection I would say, in the first place, that the question whether a given equation can be regarded as a "complete expression of the fundamental law of motion" depends simply on whether all the theorems of dynamics can be deduced from this equation, and not on how the equation itself happens to have been derived. In the second place, I quite agree that in order to handle dynamical problems successfully we must indeed be able to discuss the "effect of different forces on different bodies"; that is, we must be able to determine the inertia, or mass, of each particle under consideration. But so also must we be able to discuss the momentum and kinetic energy of the different bodies; but that is no reason why a letter denoting mass, or momentum, or kinetic energy, should appear explicitly in the *fundamental* equation. From the point of view of scientific economy, the fewer letters *that* equation contains, the better. The mass concept, like the concept of momentum or kinetic energy, is a derived concept, both historically and practically, and it seems to me a merit of the plan here advocated that on this plan the derivative character of all these quantities is explicitly apparent in the mathematical development of the equations.

So much for what may be called the force method of beginning mechanics.

A second method of developing the whole subject might be to adopt *mass* instead of *force* as the fundamental concept—as has been done, for example, by Mach and by Boltzmann. This method seems to me, however, open to three serious objections.

First, the instrument commonly taken as the fundamental means of measuring mass—namely, the beam-balance—is essentially a *gravitational* instrument, depending for its operation on the (established or assumed) equality of the gravitational fields of force at the two ends of the beam; whereas the instrument for measuring forces, at least in a readily idealized form, is a *universal* instrument, not in any way dependent on locality. For example, if a man should be placed, in imagination, at the "point of zero gravity" between the earth and the moon, it is not at all obvious how he would proceed to measure a given mass with a beam-balance; whereas, if he had a spring

[3] The "standard weight" of a particle is the force required to give the particle the "standard acceleration," 32.1740 feet per second per second; the standard weight of a composite body is defined as the sum of the standard weights of the particles of which it is composed.

balance, in the form, for example, of a grip-testing machine, he could measure the strength of the muscles of his hand, or the attraction between two bodies, just as well under those circumstances as if he were on the surface of the earth.

Secondly, if we are dealing with only a portion of the physical universe (as is always the case in practical problems), we must either introduce "forces" to account for the action of the residual portion, or else resort to very artificial conventions in regard to "imaginary masses." (It should be noted that the "mass-acceleration" of a body can not conveniently be taken as a substitute for an external force acting upon that body; for the mass-acceleration of the body, like its momentum or kinetic energy, is a quantity inherent in the body.)

Thirdly, the approach to statics, in which the concept of mass plays no part whatever, is peculiarly awkward by this route; whereas if force is taken as the fundamental concept, the problems of statics may readily be taken up either before or after the detailed study of dynamics.

While therefore it is logically possible to choose either mass alone or force alone as the fundamental concept, the latter choice seems practically preferable.

Either the force method or the mass method, I say, is logically defensible; but the method which starts with the equation $F = ma$ is neither the force method nor the mass method. My chief objection to this hybrid equation $F = ma$ is precisely this uncertain wavering between the force concept and the mass concept as the fundamental notion of the science. This wavering is, I believe, the main source of the very real difficulties which the student experiences in regard to "units"—difficulties which are not necessarily functions of the laziness or immaturity of the student, but which are felt more keenly by those of a scientific and critical turn of mind than by those of a merely practical bent. I quite agree with Professor Hoskins that any student of dynamics ought to have sufficient intelligence to grasp the idea of a *systematic system of units*, that is, a system in which certain units are taken as fundamental, and all others are derived; but I do think that the student has a right to expect that the quantities which appear in the so-called fundamental equation shall be the same as the quantities which are taken as fundamental in the system of units. *This is not the case with the equation* $F = ma$. The trouble with this equation is not that it contains mass, but that it contains *both force and mass*, while not both of these quantities are regarded as fundamental in the subsequent treatment.

The use of the equation $F/F' = a/a'$ seems to me, therefore, not merely a matter of practical convenience, but also a distinct advance in scientific precision of thought.

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GEOLOGIC HISTORY OF LAKE LAHONTAN [1]

IN reference to the summary concerning the probable history of Lake Lahontan by J. C. Jones, contained in SCIENCE, December 4, 1914, while I am much interested in Professor Jones's conclusions concerning the origin of the tufa, I feel that his statements regarding the interpretation of the age of Lake Lahontan need some important qualifications, and that his conclusions as to the probable accumulation of salines in Lahontan waters are not at all the necessary deductions from the evidence that he has cited.

Professor Jones's estimates on the age of Lake Lahontan and the quantity of salines that might have been deposited by the evaporation of its waters fail to take into account some very important considerations. The assumption that because Pyramid Lake may be and probably is a remnant of Lake Lahontan, which has never been dried up completely, therefore its salines are an index of the age of the whole larger lake seems to me erroneous. A conception of a closer interpretation may perhaps be obtained in the following way.

No one doubts that Lake Lahontan formerly rose to a height of approximately 500 feet above present Pyramid Lake and that its

[1] Published by permission of the Director of the United States Geological Survey.